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ABSTRACT

This study investigated the premise that disordered temporal order perception in retarded readers can be seen in the serial processing of both nonverbal auditory and visual information, and examined whether such information processing deficits relate to level of reading ability. The adult subjects included 20 in the dyslexic group, 12 in the reading disabled group, and 20 in the control group. Findings indicated that deficient readers, as a group, exhibited significant deficiencies in the temporal sequencing of nonverbal information. The study suggests that the part of the brain most critically involved in ordering and timing the units of perception as well as behavior is that of the left prefrontal cortex, and that the major role of this timing mechanism is to organize the structural units of language and to encode these for purposes of recall, recognition, and action. (DB)

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TEMPORAL ORDER PROCESSING IN ADULT DYSLEXICS

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INTRODUCTION

Many studies of the neurobiological basis of language have attempted to specify the underlying mechanisms of phonemic, morphemic, and syntactic analysis. An alternative to the study of language as a "mental organ metaphor" is to look for nonlanguage perceptual functions and capabilities that might serve as rudimentary operations essential for symbolization. Perhaps one fundamental ability upon which both receptive and expressive aspects of linguistic performance ultimately depends is that of human time perception. In this respect, some investigators have proposed that deficits in perceiving rapidly changing sequential information or in detecting transitional elements may serve as the primary cause of many language impairments (Tallel and Newcombe, 1978; Stark and Tallal, 1978, 1979; Tallal et al.; 1985).

With respect to reading, an important question that merits further research is how basic is temporal order perception within the constellation of functions related to reading performance? Researchers such as Shankweiler and Liberman, (1978), and Vellutino (1977) have noted that linguistic rather than temporal order deficits are the primary antecedents to reading difficulties. In contrast to this position is the possibility that reading disorders might be better attributed to a more general deficit in organizing items sequentially independent of the symbolic nature of the reading process.

RATIONALE AND PURPOSE

Despite the fact that many theorists and clinicians have speculated that a dysfunction in serializing information may be a basic cause of reading disability, such explanations have not been extensively evaluated. Apparently, Bakker (1972) is the only investigator who has developed a formal theory of dyslexia indicting sequencing deficits as a cause of the disorder. More specifically, Bakker's theory is based on the assumption that disabled and normal readers differ in general threshold for perception of temporal order. Disabled readers are presumed to have higher temporal order thresholds (require longer durations for temporal order processing) than competent readers.

There are at least two major problems with the evidence marshalled by Bakker in support of his theory. First, the experiments used to support his position were confounded by the incorporation of stimuli, such as pictures and letters, requiring verbal mediation. Since disabled readers are by

definition verbally disadvantaged, their inferior performance on serial order measures involving naming or labelling tasks might have been predicted. The second limitation of Bakker's experiments is that he failed to directly contrast disabled and normal readers by employing stimulus durations and interstimulus intervals short enough to isolate temporal order perception from other possible intervening variables such as short term memory.

The purpose of the present experiment was to further investigate the premise that temporal order perception is impaired in retarded readers as centrally derived and manifested in the serial processing of both non-verbal auditory and visual information. Another question was whether or not possible deficits in such information processing is a function of levels of reading ability.

METHOD

Subjects

The study sample consisted of three groups of subjects with normal visual and hearing acuity. All groups were matched for age, education level, social index, and full scale IQ. 20 subjects comprised the Dyslexic group. These subjects, all reading 2 SD below the mean on the Gray Oral and Wide Range Achievement tests, met the Finucci Criteria for adult specific reading disability (Finucci, Whitehouse, Isaccs, & Childs, 1984). The mean age for this Dyslexic group was 28.1 yrs., and their mean full scale Wechsler IQ was 110.3. 12 subjects comprised the Reading Disabled group. These subjects presented with histories of reading disability, read 1 SD below the mean on the same standardized tests, but upon full diagnostic screening were found not to meet the Finucci criteria for adult dyslexia. The mean age for this Reading Disabled group was 23.9 yrs., and their mean full scale Wechsler IQ was 112.5. 20 additional subjects were recruited to serve as control subjects. The subjects in the Control group had no history of reading difficulties and were found to have average or above average reading ability on the standardized tests noted above. The mean age of this Control group was 25.7 yrs., and their mean full scale Wechsler IQ was 112.0.

Experimental Design and Procedures

A portable microcomputer (Tandy - Model 200) was used to generate electronic signals which activated the stimulus apparatus. The computer-generated signals allowed for the programming of serially ordered auditory and visual stimuli, and for the adjustment of stimulus durations and inter-stimulus intervals.

Auditory Stimuli: Auditory stimuli were paired identical audible clicks presented via right and left earphones, with a duration of 1 ms and an intensity level of 85 db. One click was presented to each earphone. The test of auditory temporal order threshold began with a demonstration and instruction to the subject, who was required to verbally identify which of the two clicks was heard first, the left or the right.

In order to avoid a fusion effect, the test was initiated with an interstimulus interval of 20 ms. Subjects were then presented with stimulus pairs every 5 seconds, with 3 repetitions provided before being required to provide a response regarding the temporal order of the stimulus pair. The leading click was presented at random, with the right ear leading in half the trials, and the left ear leading in the other half.

Visual Stimuli: Visual stimuli consisted of paired right and left flashes of red light emitted from diodes, placed directly in front of the subject at eye level. Diodes were 5 mm in diameter, with a duration of 3 ms each. Their centers were separated by a horizontal angle of approximately 4 degrees. Midway between the diodes was a yellow dot which subjects were asked to fixate upon prior to flash presentations. Visual stimulus pairs were presented in a manner identical to that used to present auditory stimulus pairs.

Both auditory and visual temporal order thresholds were measured in the following manner: In a series of 10 stimulus presentations, if a subject made no more than one error of order judgement, the value of 20 ms was then recorded as the subject's temporal order threshold. If the subject made two mistakes in a series of 10 stimulus presentations, the inter-stimulus interval was increased by 10 ms, and the 10 stimulus pairs were presented again.

In this manner, the inter-stimulus interval was increased by 10 ms until a subject made no more than one mistake in a series of 10 presentations. The final temporal order threshold recorded for the modality being tested (i.e., auditory or visual) was the total sum of inter-stimulus interval increments, in addition to the initial 20 ms inter-stimulus interval provided.

RESULTS

In analyzing the findings from this investigation, mean values for auditory and visual order threshold scores, and difference values were obtained for the three subject groups.

A one-way analysis of variance and a multiple anaylsis of variance for unequal sample sizes were conducted to determine the among and within group differences for auditory and visual temporal order processing scores. Scheffe analysis was also conducted to obtain significance values for any emergent between and/or within group differences.

Figure 1 is a graphic representation of the mean scores for the three groups of readers in their temporal order processing of both non-verbal auditory and visual stimuli--represented here as (ATOP) and (VTOP), respectively. As can be seen, the Dyslexic Group was found to be most deficient in their timing operations, requiring longer durations in making accurate temporal order judgements,followed by the Reading Disabled Group and lastly by the Control Group of normal readers. This same staircase result was found for both ATOP and VTOP threshold scores.

Statistical analyses of paired reader groups were conducted to determine where significant between group differences might have occurred. This was accomplished using two-tailed probabilty tests for each pair of groups, under each experimental condition. As seen in Table 1, among group differences were accounted for only by significant differences between the dyslexic and control readers. Paired group analyses of dyslexics vs. reading disabled and reading disabled vs. controls revealed no significant between group differences for these particular comparisons. The Reading Disabled group not only

fell somewhere in the middle on reading abililty but on temporal order processisng as well. When viewed together, these results appear to indicate that proficiency in perceptual timing is required for proficient reading.

Another question in this study related to whether or not differences between auditory and visual threshold scores might exist within the reader groups. As seen in Table 2, there were no significant differences with respect to auditory vs. visual temporal order processing thresholds for any of the groups studied. The absence of such differences were interpreted as possibly implicatiing a general timing mechanism or biological clock for processing non-verbal information independant of the stimulus modality which may also play a significant role in the processing of serialized verbal information as well. This interpretation no way implys that the same neural regions are involved in processing the primary features of both auditory and visual perceptual information. However, there may exist a common neurophysiologic substrate for the proper sequencing of all temporally ordered information whatever the source.

CONCLUSION

Based on the overall findings of this investigation, we conclude that deficient readers as a group exhibit significant deficiencies in the temporal sequencing of information. While other investigators have shown that poor readers illustrate a weakness in retaining temporal sequences of verbal information, our results also implicate deficiencies in ordering nonverbal stimuli. The theoretical implications of these findings, particularly in reference to the specific role of time in the perceptual processes and memory operations involved in reading, have yet to be fully developed. Nevertheless, on the basis of the exisiting evidence, we would would like to propose that the part of the brain most critically involved in the ordering and timing the units of perception as well as behavior is that of the left prefrontal cortex. In

particular, the dorsolateral prefrontal cortex of the left hemisphere and its anatomical connections to thalamocortical and hippocampal structures appears decisive in any linguistic or segmental task which must rely on working memory to update and logically order bits of information as they are sequentially processed. More specifically, we postulate that the major role of this superordinate timing mechanism is to organize the structural units of language and to encode these for purposes of recall , recognition and action. Such a neural mechanism must have not only segmental but synthetic capacities which allow for bridging the temporal discontinuities which naturally exist between verbal sequences of information whether phonological or syntactic in form. If the device controlling the order and recall of these temporally sturctured units is deficient, then the efficiency of language processing is likewise degraded. Thus, timing operation are determinate not only of the sequence of the most elementary features of verbal behavior but also, by establishing the conditions for internal stimulus analysis and fine temporal discrimination, serve to cohese such features into hiearchical patterns of meaning.

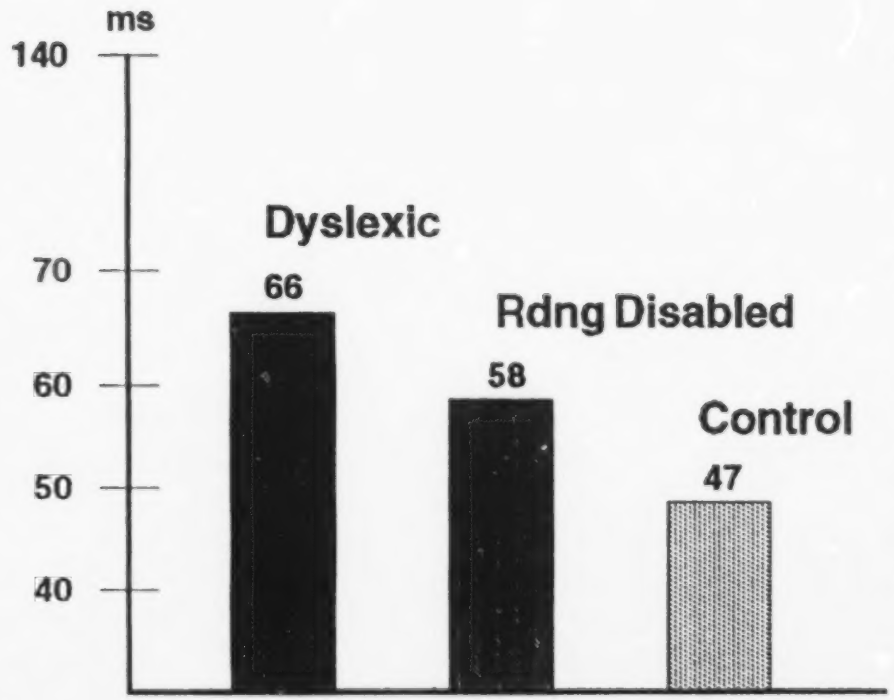
t-Values and 2-Tailed Significance of Between Group Differences on Auditory and Visual Temporal Order Processing

CONDITION	t-VALUE	DEGREES OF FREEDOM	2-TAILED PROB.
Dyslexics vs. Reading Disabled:			
Auditory	.78	13.50	.450
Visual	1.05	15.32	.308
Reading Disabled vs. Controls (Normal Readers):			
Auditory	.95	13.72	.358
Visual	1.03	12.39	.322
Dyslexic vs. Controls (Normal Readers):			
Auditory	2.76	42.74	.009 *
Visual	3.26	43.00	.002 *

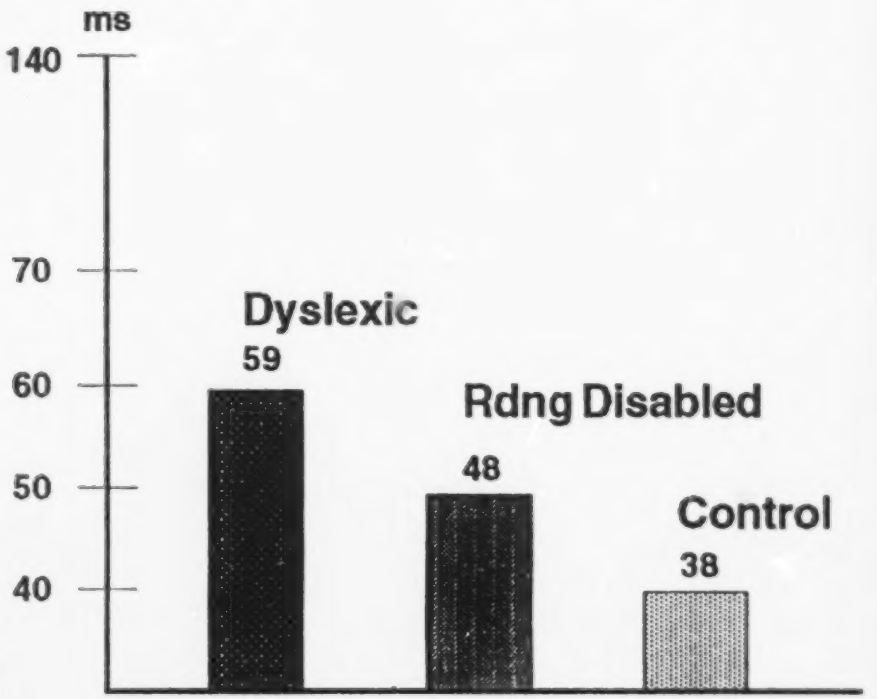
* $p < .01$

Temporal Order Processing

By Reader Group



ATOP Threshold



VTOP Threshold

Within Group Comparison of Auditory and Visual Temporal Order Processing
Means, Standard Deviations, and t-Values of Difference Scores by Group

GROUP	n	MEAN	SD	df	t-VALUE
Dyslexic	26	7.69	30.89	25	1.27 *
Rdng Disabled	10	10.00	26.25	19	1.20 *
Control	10	9.50	21.88	9	1.94 *
Entire	56	8.75	26.70	55	

* $p > .05$

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